The Comparative Analysis of Energy Consumption between OLSR and ZRP Routing Protocols

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Abstract —The Mobile Ad-hoc Network (MANET) routing protocol generates a different performance when it is implemented in a different network scenario. It is a challenge to find the suitable characteristic of MANET protocol which conforms to a certain network condition scenario. Generally, many studies have been done to analyze the performance of MANET protocol. However, those studies are related to the scope of topology-based protocol. Based on that scope, the easy way to explore the MANET protocol is to compare between the Proactive protocol and the Reactive protocol. Alternatively, there is a protocol which is a combination of both, namely the Hybrid protocol. Studies which are related to the comparison between the Proactive protocol and the Hybrid protocol, or reviews which are related to the comparison between the Reactive protocol and Hybrid protocol have been widely executed. Nonetheless, there are still little studies related to the MANET protocol which focus on the character of its energy usage. Based on this information, this study is going to analyze about the comparison of energy usage in the MANET network between the Proactive which is performed by OLSR (Optimized Link State Routing Protocol) and the Hybrid which is presented by ZRP (Zone Routing Protocol). This study gives a result that the ZRP total energy consumption is fewer than the OLSR total energy consumption, nevertheless when the destination nodes are located in the sender nodes radius area, the OLSR can maintain its energy use better than the ZRP.

Index Terms—MANET, OLSR, ZRP, energy consumption, mobility model, proactive, reactive

I. INTRODUCTION

Mobile Ad Hoc Networks (MANET) is a set of mobile nodes which move dynamically, and the form of their network topology is independent, without using fixed network infrastructure [1]. The MANET network has limitations in terms of bandwidth capacity, as well as energy capacity [2]. By its advantages which are dynamic movement and are not dependent infrastructure, it produces different performance when it is implemented in different network scenario [3].

Generally, the studies related to MANET are about topology-based, although there are some other variants which are not topology-based [4]. Several the MANET protocols which are topology-based are OLSR, AODV (Ad hoc On-Demand Distance Vector), and ZRP [4].

According to their routing protocol mechanism, the topology-based MANET protocol is divided into three types. The types are Proactive, Reactive, and the combination of both, namely Hybrid. The characteristic of the Reactive is that the establishment of its routing network is based on the required data communication, and the routing is not always created periodically [5]. On the other hand, the Proactive determines its routing network through the information based on its routing table and the routing is updated regularly [5]. The Hybrid uses the Reactive function to create a topology when nodes are in high mobility condition including when the distance between nodes in a far-off scale. Meanwhile in the network which the distance between nodes are in a proximity scale, including the nodes are in the low maneuverability condition, the Proactive function is used [1], [5].

A good routing protocol must be able to keep its energy usage as low as possible in route finding and also in data transmission [3]. It must be done to prevent its node from getting down which can create disrupted data communication in the MANET network. Hence, how to create a good scenario which can regulate node energy usage properly on the MANET network becomes very important.

In addition, many studies explore the Reactive, the Proactive, and the Hybrid in comparison, but focusing on details beside energy use problem [6]–[8]. Therefore, this study is going to observe the use of node energy in the MANET network, especially between the Proactive which is shown by OLSR and the Hybrid which is expressed by ZRP.

II. RELATED WORKS

A. MANET

The MANET network is composed of a set of mobile nodes, and those nodes can move dynamically and also can develop a topology according to the existing condition despite it is an ad-hoc network [1]. There are advantages and also disadvantages of the MANET which can be seen from its characteristics such as dynamic topology which allows its nodes to move dynamically, although the nodes have relatively smaller bandwidth limit than non ad-hoc network, and also its nodes entirely depend on their portable battery, as well as the MANET network is generally vulnerable to the security threat [2].

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1) Topology-Based routing protocol

Mostly, the study of the MANET is related to topology-based. However, the studies of MANET energy consumption are still fewer than the routing protocol studies which focus on network performance.

TABLE I: THE NUMBER OF MANET STUDIES IN THE LAST 3 YEARS

Topic	Sub Topic	The Number of Studies
Routing Protocol	Proactive	75
	Reactive	92
	Hybrid	83
Energy Consumption		169

Based on Table I, in the last 3 years (January 2014 to December 2017), by using IEEE indexing, it can be shown that the studies which are related to the routing protocol and the energy consumption in MANET. Thus, those last studies becomes a reason why this current study emphasizes the use of MANET energy.

Based on the function, the MANET topology-based routing protocol is categorized into 3 types which are Proactive, Reactive dan Hybrid.

a) Proactive (Table-Driven) routing protocol

Basically, the Proactive which is also known as Table Driven Protocol is similar as the common internet routing protocol nowadays, such as Routing Information Protocol, Distance-Vector, Open Shortest Path First and Link State [1]. This protocol maintains its routing table by using routing information learned from neighbor nodes periodically. Each node can use one or more routing tables from other ones to update its routing information by broadcasting and propagating [1]. This condition creates high routing overhead which can consume high bandwidth. However, the route finding delay to the destination node relatively decreases. It happens because of the probability of the routing table which is ready to be used for data communication increases [1]. The examples of Proactive are Destination Sequence Distance Vector (DSDV), and Optimized Link State Routing (OLSR) [1].

The Proactive has a node searching mechanism which is located outside of the direct transmission range. This mechanism is needed because sometimes nodes are not going to send or are not going to receive information when the channel condition is not good [9]. To solve this problem, Proactive uses Tree Algorithm to determine the route. Each node sends data packets to the nearest node and to make a branch form (like a tree). After the topology route is set, to determine which route is correct to get to the destination node, then the search algorithm is used, namely Breadth First Search Tree [9].

b) Reactive (On-Demand Driven) routing protocol

The Reactive which is also known as Demand Driven Protocol does a route finding mechanism just only when it is needed. This protocol executes a Route Discovery just before does a data communication by spreading RREQ (Route Request) packet [9]. A received node is going to run a reply by using RREP (Route Reply) packet. Beside route finding mechanism, there is also route maintenance if there is a route failure in the topology by using RERR (Route Error) packet. As known that the maintenance of routing table is not executed periodically. That is why the Routing Overhead of Reactive relatively decreases. The Reactive routing table is not generated periodically that it differs from the Proactive. Then if there is a node which runs a Route Discovery, it is going to produce a high Route Discovery Delay [1]. Some examples of Reactive are Ad hoc On-Demand Distance Vector (AODV), and Dynamic Source Routing (DSR) [1].

c) Hybrid routing protocol

The Hybrid combines both the Reactive and the Proactive [1]. This protocol utilizes the advantages of both protocols. Firstly, it can use Reactive mechanism by normalizing the generated delay which is created when the Route Discovery is executed, and also by reducing Routing Overhead [9]. Secondly, the mechanism which is applied by Hybrid is the Proactive if the distance between nodes is relatively not far. On the other hand, if the range between nodes is so immoderate, then the Reactive is going to be chosen to be executed [1].

2) OLSR

The OLSR is the Proactive protocol and is created as optimization of Link State protocol [8]. By using the OLSR, if there is a change on the topology, this condition can cause the information related to the topology overwhelms to all the nodes which are connected to the network. To decrease the presence of the overhead, then Multi Point Relay (MPR) is applied [9].

The OLSR has several message types, such as [9]:

a. HELLO – it has a function to give a searched route information and to inform a location of a neighbor node including a link type which is used by the sender.
b. Topology Control – it has a purpose to determine a routing table by forwarding a list of nodes which are chosen as MPR.
c. Multiple Interface Declaration – it has a function to give a report if there are more than one interface on the node.
d. Host and Network Association – it has a function to report the information of a certain network presented such as Ethernet network.

In addition, the character of the OLSR is that all its nodes send a HELLO message periodically to find the other neighbor node in their network. There are three types of neighbor, which are Not Neighbor, Symmetrical Neighbor, dan MPR Neighbor [9].

a) Multipoint Relays (MPR)

The OLSR uses the MPR mechanism to minimize the overhead which is created. The overhead happens because of the existing of packet retransmission. It must be done because almost all neighbor nodes can read a packet which is already sent by every node [9]. Every node can choose its neighbor node as MPR node which becomes the only way to transmit packets by broadcasting.

3) ZRP

The ZRP is a routing protocol which is designed by combining features of both the Reactive and the Proactive [10]. The Proactive uses much bandwidth to maintain routing information. On the other hand, the Reactive has a weakness such as when it does a Route Discovery, it creates long RREQ delay [10]. Basically, the Hybrid tries to reduce those weaknesses. The ZRP is designed to accelerate the transmission and to reduce the overhead by choosing the most efficient protocol which is used on every route [10]. The nodes which are located in IARP (Intra-zone Routing Protocol) area, they exchange their routing information to each other by using Proactive mechanism. However, to be able to communicate to other node which is placed in outside IARP zone, then there is other protocol used, namely IERP (Inter-zone Routing Protocol) [10]. The RREQ packets are sent to all border nodes which have a duty to forward RREQ packets when the destination node is not present in the same as the sender zone. The IERP itself uses special mechanism of a standard flood search called as border-casting which the mechanism is supported by BRP (Border-cast Resolution Protocol) [10].

a) The Architecture of ZRP Network

Fig. 1 shows that the radius of the ZRP area. The radius area of S node is structured by all nodes around it which are A node, B node, C node, D node, E node, and F node, including all other nodes which become neighbors of the nodes around S node which are G node, H node, I node, and J node which are determined as border nodes [9]. K node is counted as the node which is placed outside of S node radius area [9]. If the data communication range is in the S node radius area then the S node is going to use IARP mechanism for data communication. In contrast, if the data communication range cannot be reached by the S node radius area then the S node is going to use IERP mechanism for data communication [9].

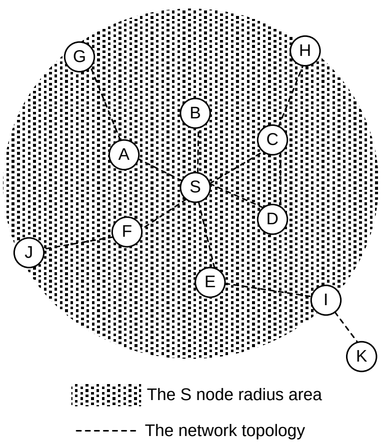

Fig. 1. The architecture of ZRP network [9].

b) The Architecture of ZRP Components

The ZRP also implements Broadcast Routing Protocol (BRP). This protocol is also applied to establish a list of nodes (which is given by the IARP protocol) based on routing information which is collected and to spread searched route request between the zone (IERP) in the network [9]. The way executed is by sending HELLO beacon message in the certain time interval to find node existence. Fig. 2 explains the architecture of ZRP components.

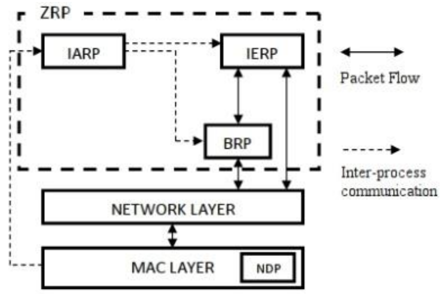

Fig. 2. The architecture of ZRP components.

B. Network Simulator 2 (NS2)

Network Simulator 2 is an event-driven simulator which is specifically designed for observing network computer and data communication in the network [11]. NS2 is developed by using 2 programming languages which are [11]:

1. C++ becomes the first. It is a library which contains event scheduler, protocol, including network component which is implemented by the user for the simulation. C++ is used as a library because it can support the simulation to run quickly, even the simulation uses very big number packets of data.
2. Tcl/Otcl is the second programming language which is used as a simulation script. It is written by a user, and it acts as an interpreter. On the other hand, Tcl gives a response if there is a syntax failure and if there is a script which changes suddenly.

The output result of NS2 simulation is a text-based file which the format is .tr, and also an animation-based file which the format is .nam. To interpret an output result as an interactive graphic then tools which are NAM (Network Animator) and Xgraph are used. To analyze a user network behavior, the user can extract a relevant part from the text-based result and can change it into other form which can be understood easily.

1) The Consumption Energy of MANET

The energy usage in MANET network can be modeled by simulated by using some models. The model then is going to be used as the source to make a scenario of MANET network simulation. There are several models which are known based on preliminary studies such as [1] [3]:

- Network-Size Model – The size of topology network gives big influence to MANET network energy consumption, especially when Route Discovery process and multi-hop data transmission are executed. Even the network size can give an effect to the node consumption energy, but each MANET protocol has its mechanism to adapt to every change in the network [3].

- Constant-Speed Model – Node speed also affects MANET network energy consumption. The faster the node, the bigger the energy consumption [3].
- Floating-Speed Model – Node accelerating also gives an impact to MANET energy consumption. The bigger the accelerate, the bigger the energy used [3].
- Pause-Time Model – When there is a node movement from a started point to a destination point, sometimes there is an interlude. The longer the interlude, the bigger the energy saving [3].
- Different Node Density – If the number of MANET nodes become bigger, this condition can increase the energy consumption which is generated by every MANET network nodes [1].

Even there are several models for making the MANET network simulation, this study is only going to compare between the OLSR and the ZRP by using Network-Size Model and Different Node Density as the modified increasing of the sender and the receiver nodes.

2) Energy consumption model

Hence, the equation which can be used to calculate the energy consumption of packets which are transmitted by a node. It can be followed as [2]:

$$E(p) = i * v * t_p \quad (1)$$

which i is an electric current, v is an electric voltage, and t_p is the time which is needed to transmit the packet p. The unit which is applied to represent the energy used is Joule [2].

III. Problem Definition

Generally, many studies about MANET are related to protocol performance and its services in the computer network. However, the number of studies which are related to the energy consumption used by MANET nodes are still rare.

The importance related to the observation of the MANET energy consumption, especially in the ad-hoc network, because the use of node energy is not spread to every node in MANET network evenly. If the certain nodes which have an important role to deliver packets use very high energy precisely then this condition makes the delivery process between the sender and the receiver is going to be broken. Based on that information, the study which is related to energy consumption in the MANET network becomes crucial.

IV. Proposed Method

The first step in this study is to acquire the role of OLSR and ZRP protocols to determine the best scenario and the best topology for the simulation. There are several models and parameters which can be used to simulate both protocols. The parameters which are applied in this study are related to both models, namely Network-Size Model and Different Node Density. Both models are used in order to know the energy consumption used by the OLSR and the ZRP in the MANET network. The network topology is designed which has relatively wide area and has receiver nodes which their number becomes bigger among the increased time. Based on the models used, the focus of this study is stressed about the energy of transmitters (sender nodes) and intermediate nodes (channel nodes). It is going to be executed because both types of nodes are assumed as the nodes which use bigger energy than other types of nodes.

A. The Topology of MANET Network

The initial topology before the nodes move or just before the simulation runs can be shown in Fig. 3. The network consists of 20 nodes and the nodes consist of sender nodes, channel nodes, and destination nodes.

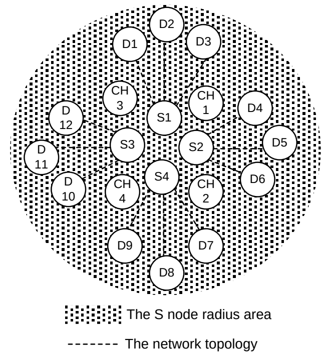

Fig. 3. The initial nodes position before the simulation starts.

Fig. 3 presents the network topology which is used by the simulation. There are several types of nodes which are:

- The type of sender nodes (S1-S4) which has a function as packet senders.
- The type of channel nodes (CH1-CH4) which has a function to deliver data from sender nodes to destination nodes if it is needed.
- The type of destination nodes (D1-D12) which has a function as packet receivers.

B. System Design

After the network topology is determined based on the models which are chosen then the analysis of each MANET node energy consumption is going to be executed by using Network Simulator 2 (NS-2).

1) Initialisation

1. At the beginning of simulation, all nodes become closer which are determined as Figure 3.
2. The sender nodes are located in the center of the network topology. The channel nodes and also the destination nodes move slowly to evade the sender nodes.
3. The channel nodes are placed between the sender nodes and the destination nodes. They deliver the data from the sender nodes to the destination nodes if the destination nodes area are seated outside of sender nodes radius area.
4. Each nodes type has a different pace.
5. The delivery of packets uses UDP service. So that the delivery service is going to be simulated by using Constant Bit Rate (CBR).

6. The delivery of each packet is going to use 512 bytes per packet for transmission.

C. The Scenario of Simulation

In this study, the observation is done using 2 different scenarios. The scenarios are analyzed based on the time of simulation. The result of the simulation is analyzed based on several factors such as the topology changes as the impact of the destination nodes movement, including the increasing number of destination nodes which receive the packets from sender nodes.

The scenarios are executed to know about the energy consumption used by MANET network, before and after the network topology changes. The important point for this simulation is that the change of the network topology happens when the destination nodes just start to move outside of the sender nodes radius area, and the channel nodes just begin to deliver the packets from the sender nodes to the destination nodes. This is the way to calculate the energy used by each protocol which is counted before the topology changes and after the topology changes. After the results of the energy calculation are collected, then the results are going to be compared.

TABLE II: THE CONFIGURATION OF MANET NETWORK SIMULATION

Parameter	Value
Simulation time	200 s
Dimension	1000 m × 1000 m
Wireless radio range	250 m
The number of mobile node	20 nodes
Node speed	1-4 m/s
Traffic type	(CBR) 512-byte per packet
Initial energy	20 Joule

1) Scenario 1

In this scenario, the OLSR and the ZRP are simulated in the condition which is the sender nodes send the packets to the destination nodes without using the channel nodes. So that in the initial network, the channel nodes act not as an intermediate in the MANET network.

Then as the time goes on, the destination nodes move outward away from the sender nodes. Similarly, the channel nodes move outside from the sender nodes. So that it is going to happen that the topology changes due to the destination nodes out of the sender nodes radius area, and finally the channel nodes are going to be used as intermediary nodes to deliver the data packets from the sender nodes to the destination nodes. The sender nodes move at the low speed of 1 m/s in the close range, the channel nodes migrate at the medium speed of 2 m/s, and the destination nodes move at the speed of 4 m/s in the farthest range. The simulation time adopted is 200 second in order to explore how many energy used by each node before and after the network topology changes.

When the network routing changes, the OLSR is going to use the mechanism of Proactive. On the other hand, the ZRP is going to use the operation of Reactive. The OLSR is going to nominate the channel nodes (CH) as MPR nodes to transmit the packets, and the ZRP is going to set the border nodes to run using BRP protocol to minimize the energy consumption when they deliver the packets from the sender nodes to the destination nodes.

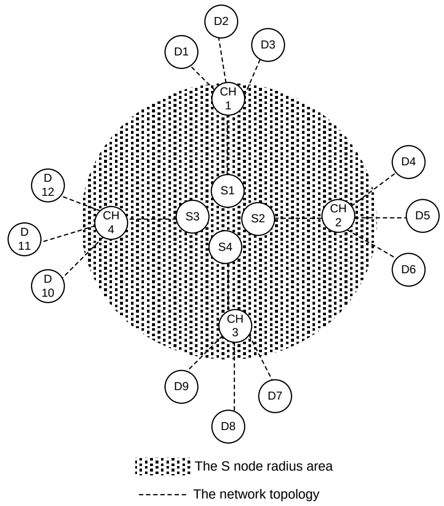

Fig. 4. The network topology used for scenario 1.

Fig. 4 exposes the final position of the network topology for scenario 1. This scenario is going to use 20 nodes and the simulation is executed three times. As long as the process repetition, the number of the destination nodes (D) are going to be added. At the beginning, each sender node (S) only send the packets just to one destination node (D). Then the packets is going to be sent repeatedly with the additional number of the receiver (D). Finally, each sender node (S) send the packets to three destination nodes (D) via the channel node (CH) simultaneously.

2) Scenario 2

Fig. 5 exhibits the position of nodes when the network routing still does not change. The sender nodes (S) directly send the packets to the destination nodes (D) without using the channel nodes (CH).

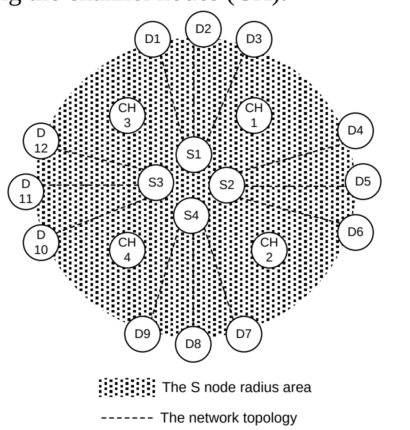

Fig. 5. The network topology used for scenario 2.

This scenario uses 20 nodes. Three times of simulation are executed by adding the number of the destination nodes (D) from one node to three nodes for each sender node (S).

Based on the results of both scenarios, then the calculation to estimate the energy needed when the network routing changes can be done. The estimation can be done by reducing the total energy used in the scenario 1 with the total energy used in the scenario 2. The composition which is estimated is based on:

1. The total energy needed by all nodes.
2. The total electrical power required by all sender nodes (S).
3. The total energy used by all channel nodes (CH).

V. Analysis and Discussion

The calculation of energy needed is going to be analyzed and it is going to be parted into three pieces which are:

- Counting the energy consumption of MANET network by using simulator from the beginning of the time to the time t = 200 second.
- Calculating the energy needed of MANET network by using NS2 from the beginning of the time until the end of time as long as the network routing does not change.
- Estimating the energy needed of MANET network by using NS2 simulator from the beginning of the network routing just changes to the time t = 200 second.

A. The Consumed Energy Calculation of the Network from the Beginning of Time to the Time t = 200 Second

In this part, the consumed energy of the OLSR and the ZRP are going to be analyzed by using the range of time between the time t = 0 second and the time t = 200 second. The energy calculated are the electrical power of the sender and the channel nodes before and after the topology changes including the changed number of the destination nodes.

TABLE III: THE CONSUMED ENERGY RELATED TO THE NUMBER OF THE DESTINATION NODES

	The Energy Consumption (Joule)					
	OLSR			ZRP		
Node	1 (D)	2 (D)	3 (D)	1 (D)	2 (D)	3 (D)
S1	18.01	20	20	18.85	20	20
S2	18.04	20	20	18.83	20	20
S3	18.03	20	20	18.80	20	20
S4	18.02	20	20	18.82	20	20
CH1	15.95	18.03	16.44	16.46	16.27	15.34
CH2	15.99	18.01	16.31	16.41	17.11	15.17
CH3	15.99	17.91	16.35	16.48	17.39	15.75
CH4	15.98	17.88	16.69	16.50	17.07	15.44
Total (20 nodes)	272.11	295.38	289.91	283.55	294.45	289.43

As an explanation of Table III which is related to the OLSR, when S1 node (the sender node) sends the packets only to one destination node (D), it needs 18.01 Joule energy. When S1 node sends the packets to two destination nodes, it needs 20 Joule energy. So it goes on continuously.

Based on the information of Table III, according to the total energy needed by MANET network from the time t = 0 second to the time t = 200 second, it can be said that the energy consumption of the OLSR is fewer than the energy needed by the ZRP when the sender node only transmits the packets to one destination node. However, as the increasing number of the destination nodes which receive the packets from the sender nodes, for all nodes, the ZRP tends to be more efficient than the OLSR.

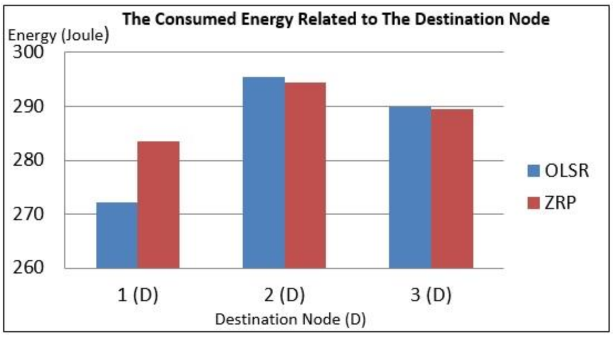

Fig. 6. The consumed energy related to the destination node.

Fig. 6 displays the comparison of the total energy consumption between the OLSR and the ZRP in the range of time between the time t = 0 second and the time t = 200 second.

B. The Consumed Energy Calculation of the Network from the Beginning of Time to the Time Before the Topology Just Changes.

In this part, the consumed energy of the OLSR and the ZRP is going to be analyzed by using the scenario 2. After the scenario 1 is finished executed, the value of time t before the network routing just changes is collected.

The range of the OLSR time for run is fewer than the range of ZRP time when both time ranges are collected from the beginning until before the network routing just changes. It can be said that the change of network routing of the OLSR is faster than the change of network routing of the ZRP. This condition can be understood because the OLSR is more aggressive to update its routing table than the ZRP, even though both protocols use the same mechanism namely the Proactive.

Based on the simulation, it is gathered that the time before the network routing just changes is at the second of 79 for the OLSR, and is at the second of 86 for the ZRP.

The energy consumption needed by the sender nodes and the channel nodes of both protocols before the network topology just changes can be seen on Table IV.

As an explanation of Table IV, according to the ZRP protocol, when S1 node (the sender node) send the packets to one destination node, it needs the energy of 8.03 Joule. Then, when the S1 node transmits the packets to two destination nodes, it needs the energy of 10.49 Joule. So it goes on continuously.

For the Proactive mechanism which the destination nodes (D) are located on the sender nodes (S) radius area, the OLSR uses the energy consumption more efficient than the ZRP. In this simulation, the channel nodes (CH) is not being an intermediate between the sender nodes (S) and the destination nodes (D). So that the energy consumption of the channel nodes in the simulation just for only the movement. So that, particularly, the focus in this simulation just to compare the energy used by the sender nodes (D) of both protocols.

TABLE IV: THE CONSUMED ENERGY RELATED TO THE NUMBER OF THE DESTINATION NODES BEFORE THE TOPOLOGY JUST CHANGES

	The Energy Consumption (Joule)					
	OLSR			ZRP		
Node	1 (D)	2 (D)	3 (D)	1 (D)	2 (D)	3 (D)
S1	6.89	9.53	12.16	8.03	10.49	13.04
S2	6.91	9.52	12,14	8.04	10.53	13.12
S3	6.91	9.57	11.9	7.96	10.49	13.02
S4	6.89	9.55	11.98	8.02	10.49	13.13
CH1	4.36	4.83	4.97	5.28	5.41	5.63
CH2	4.40	4.84	4.86	5.23	5.42	5.63
CH3	4.40	4.73	4.8	5.3	5.4	5.61
CH4	4.40	4.68	5.01	5.32	5.4	5.7
Total (20 nodes)	98.16	114.49	128.73	115.79	129.66	144.91

Even the focus of analysis just to compare the sender nodes energy consumption of both protocols, however, the trend of energy used shows similar trends with the energy consumption of all nodes. The total of the energy consumption which is related to the additional number of the destination nodes before the network routing just changes can be seen in Fig. 7.

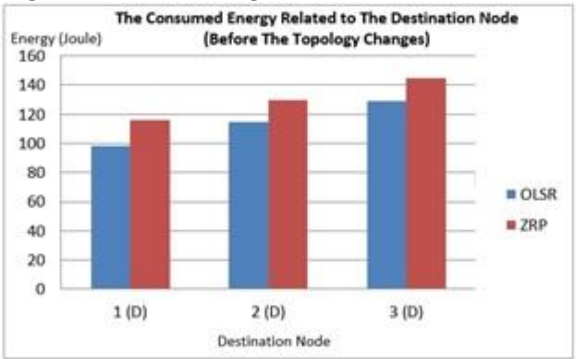

Fig. 7. The consumed energy related to the destination node (before the topology just changes).

Based on Fig. 7, it can be shown that the number of the destination nodes which receive the packets affects the energy consumption of MANET network for both protocols even it is for the network topology which its network routing does not change.

It can be seen that the bigger the number of the destination nodes, then the bigger the energy consumption needed.

In the scenario 2, the OLSR is more efficient for the energy used than the ZRP. It happens because before the topology changes, the destination nodes are still located in the sender nodes radius area. Then the routing creation of OLSR routing table is more efficient than the routing generation of ZRP routing table.

C. The Consumed Energy Calculation of the Network from the Beginning of Time to the Time t = 200 Second

The calculation of the energy consumption when the network topology just changes its network routing is counted by reducing the total energy acquired of MANET network in the first scenario with the total energy used of MANET network in the second scenario.

Based on the simulation in the first scenario that the time before the network routing just changes is at the second of 79 for the OLSR, and is at the second of 86 for the ZRP. Thus the calculation of the energy consumption for the OLSR when the network topology just changes is from the time t = 80 to the time t = 200. For the ZRP is from the time t = 87 to the time t = 200.

TABLE V: THE CONSUMED ENERGY RELATED TO THE NUMBER OF THE DESTINATION NODES AFTER THE TOPOLOGY JUST CHANGES

	The Energy Consumption (Joule)					
	OLSR			ZRP		
Node	1 (D)	2 (D)	3 (D)	1 (D)	2 (D)	3 (D)
S1	11.12	10.47	7.84	10.82	9.51	6.96
S2	11.13	10.48	7.86	10.79	9.47	6.88
S3	11.12	10.43	8.1	10.84	9.51	6.98
S4	11.13	10.45	8.02	10.8	9.51	6.87
CH1	11.59	13.20	11.47	11.18	10.86	9.71
CH2	11.59	13.17	11.45	11.18	11.69	9.54
CH3	11.59	13.18	11.55	11.18	11.99	10.14
CH4	11.58	13.2	11.68	11.18	11.67	9.74
Total (20 nodes)	173.95	180.89	161.18	167.76	164.79	144.53

Based on Table V, it can be examined that the energy needed by the ZRP network which utilizes the sender nodes and the channel nodes is fewer than the OLSR network. It happens because when the network routing just changes, the ZRP uses the Reactive mechanism. On the other hand, the OLSR still applies the Proactive mechanism which needs more energy than the Reactive mechanism.

The total energy consumption which is related to the destination nodes after the network routing just changes can be seen in Fig. 8.

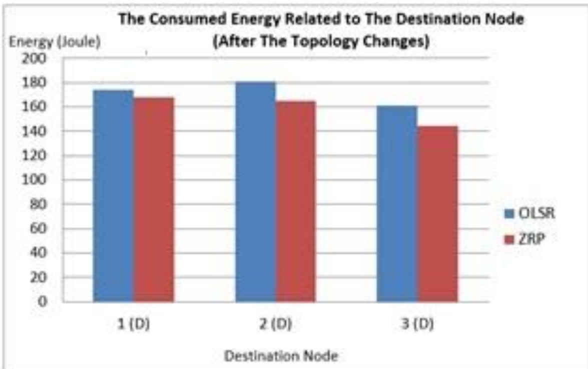

Fig. 8. The consumed energy related to the destination node (after the topology just changes).

Fig. 8 shows the values which are collected by reducing the total energy consumption of MANET network simulated in the scenario 1 with the total energy consumption of MANET network simulated in the scenario 2.

VI. Conclusions

Based on the simulation analysis which observes about the energy consumption of the ZRP and the OLSR, it can be examined that the OLSR which represents the Proactive has the most efficient mechanism to deliver the packets when the destination nodes are located in the sender nodes radius area. It happens because the OLSR can maintain the updated routing table more efficient than the ZRP. It can be seen that the energy consumption needed by the OLSR in the MANET network simulation is fewer than the energy consumption used by the ZRP in the MANET network simulation.

The ZRP which represents the Hybrid has the most efficient mechanism to deliver the packets when the destination nodes are located out of the sender nodes radius area. It happens because the ZRP uses the Reactive mechanism when the destination nodes are not placed in the sender nodes radius area. It can be seen that the ZRP energy consumption is fewer than the OLSR energy consumption.

The ZRP which represents the Hybrid uses the Proactive mechanism when the destination nodes are located in the sender nodes radius area. However, the updated mechanism of the ZRP routing table is not as efficient as the updated mechanism of OLSR routing table. It can be seen that the ZRP sender nodes energy consumption is higher than the OLSR sender nodes energy consumption.

By the way, as the increasing of the MANET network density, the ZRP energy consumption tends to be more efficient than the OLSR energy consumption. It can be seen by examining the channel nodes energy consumption and the destination nodes energy consumption together.

All in all, the total energy consumption of the ZRP is fewer than the OLSR, and it has the most efficient energy consumption for transmitting packets for all simulation.

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